

ANALYSIS OF UPFC USING ANN CONTROLLER FOR REAL AND REACTIVE POWER COORDINATION

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ABSTRACT

This paper includes a modified real and reactive power coordination compensation controller for a unified power flow controller (UPFC). The primary control for the UPFC is that the series control of converter of the UPFC controls the transmission line powers like real/reactive power flow and the shunt control of converter of the UPFC controls the UPFC bus voltage or shunt reactive power and the DC linked capacitor voltage. In steady state analysis, the real power required for the loads of the series converter is received by the shunt converter of the UPFC. To reduce instability/loss of DC linked capacitor voltage in transient state, modified real power coordination with ANN controller has been modeled.

The necessity for reactive power control and coordination controller for UPFC arises from the fact that excessive bus voltage (the bus to which the shunt converter is connected) simulations occur during reactive power flow transfers. A modified reactive power control and coordination controller has been modeled to obstruct excessive voltage variations during reactive power flow transfers. MATLAB-SIMULINK simulation results have been used to show the improvement in the performance of the UPFC control with the modified real power and reactive power coordination ANN controller.

KEYWORDS: FACTS, Unified Power Flow Controller (UPFC), Coordination Controller, ANN Controller

INTRODUCTION

INTRODUCTION OF UPFC

In a competitive electricity market, installation of the Unified Power Flow Controller (UPFC) can improve power transfer capability and help market participants keep their schedules very close to preferred ones and at the same time may retain the competitive behavior of participants. Putting the UPFC in service may assist system to operate within its physical limits and reduce total generation cost associated with out-of-merit order caused by constrained transmission. However, a competitive electricity market necessitates a reliable method to allocate congestion charges, transmission usage, and transmission pricing in an unbiased, open-accessed, basis. Therefore, it is usually necessary to trace contribution of each participant to line usage and congestion charges, and then to calculate charges based on these contributions. It has been a common practice to use distribution factors to calculate these contributions^[4].

In this paper, derives relationships to UPFC model and its impact of UPFC on line flows and transmission usage where modified admittances and distribution factors that in the model effects of utilizing UPFC on power line flows and system demand for loads. The relationships obtained shows the bus voltage angles are attributed to each of changes in generation, additions of UPFC, and changes in admittance matrix caused by inserting UPFC in transmission lines. The relationships obtained can be implemented for the use of allocating usage and payments to users of transmission

network and control of devices used in the network. The relationships derived are applied to an IEEE test systems, where the results demonstrate how transmission usage is affected when UPFC is adopted^[3].

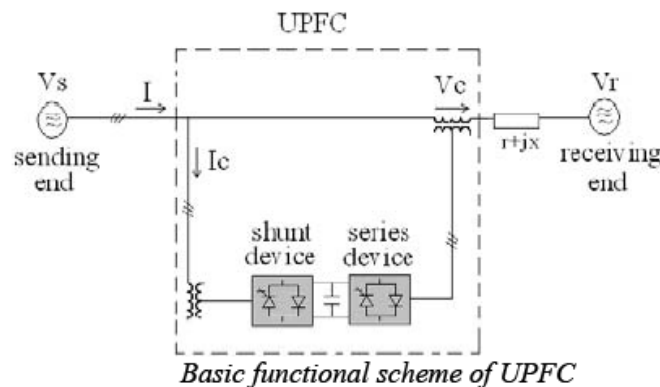


Figure 1: Basic Functional Scheme of UPFC

The series power control of converter works to use a constant balanced of sinusoidal load voltage. The shunt control of converter fluctuates the DC linked voltage and compensates for the reactive current of the primary source within the required current of the converters. To obtain the required rated capacity for the series and shunt power converter, the relationship between the converter's capacity and the source and load power factor at constant series/shunt compensation voltage is simulated. The required rated capacity of the series and shunt power converters is minimized by greater than 50% compared with that of a old series power converter. The effectiveness of the proposed load voltage compensation technique using the series and shunt power converter.

The IEEE 39 test bus system which contains of total 10 generator bus and remaining load bus, a load flow method is carried out and found bus no 26 & 39 are weak, voltage less than one per unit at these bus.

UPFC controllers are connected between 26 & 39 bus with two different controllers PI and ANN and are represented.

TUNING OF PI CONTROLLER

A PI controller reciprocates to an error signal in a closed control loop and trials to adjust the parameters of controlled quantity to achieve the desired system response with respect of step input. The desired parameter can be any measurable system quantity such as parameters like speed, torque, or flux. The advantage of the PI controller is that it can be modified empirically by controlling one or more gain values and observing the change in system response.

Tuning of PI Controllers parameters

Proportional-integral (PI) controllers parameters have been modeled in process control industries and its applications. Hence various latest techniques using PI controllers to achieve better performance index for system response are presented. The technique's to be modeled for determining the proportional integral constants of the controller, called *Tuning*, and depends upon the dynamic output of the plant^[2].

This first order error is manipulated by the controller (PI) is to produce a reference signal for the plant according to the relationship.

$$U(s) = K_p (1 + 1/\tau_i s)$$

$$\text{Or in time domain } U(t) = K_p [e(t) + (1/\tau_i) \int e(t) dt]$$

Where K_p = proportional gain

τ_i = integral time constant

Zeigler- Nichols Rules for tuning PI controllers

First Condition: The S-shaped function of the response is divided by two constants, the dead time L and the time constant T as mentioned. These constants can be estimated by drawing a tangent to the S-shaped curve function at the operating point and state value of the output. From the response of this type the plant can be mathematically modeled as first order system with a time constant T and delay time L as shown in block diagram.

The gain K corresponds to the steady state value of the output C_{ss} . The parameters of K_p , T_i and T_d of the controllers can then be estimated as below:

$$K_p = 1.2(T/L)$$

$$\tau_i = 2L$$

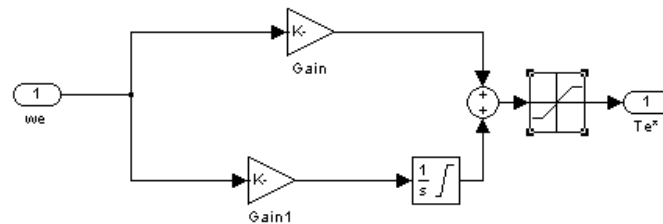


Figure 2: Mathematical Model

INTRODUCTION OF ANN

Neural networks deals with simple elements which are operating in parallel connection. These elements are triggering or fired by biological nervous systems. As in biological in nature, the network function is estimated mainly by the connections in between elements. Neural network is a trained network which is to perform a particular function by varying the values of the connections (weights) or gains between each element. Commonly Neural Networks are adjusted, or trained, so that a particular input leads to a specific target output. There, the network is adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically many such input/target pairs are used, in this supervised learning, to train a network.

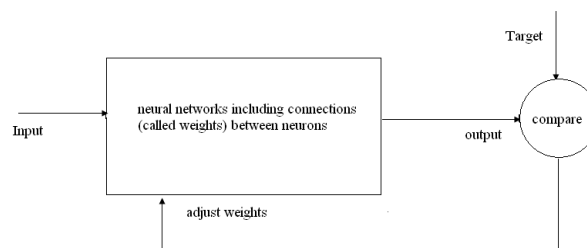


Figure 3: Block Diagram of Neural Network

Training of a neural network generates by making weight and bias variations based on an entire group (batch) of input vectors of elements. Maximum training changes the weights and biases of a network as necessary after presentation of each input vector of element. Feed forward training is sometimes known to as "on line" or "adaptive" training. Neural networks can be trained to perform even complex functions in large fields of application including classification, speech pattern recognition, identification, and vision and automatic control systems. Today neural networks can be trained to solve the problems which are difficult for conventional computers or human beings^[1].

The supervised or with teacher training methods are commonly used in various applications, but other neural networks can be trained and obtained from unsupervised training latest techniques or from direct design implementation methods. Unsupervised or without teacher networks can be used, for a chance, to identify multiples of data. Certain kinds of linear neural networks and Hopfield networks can be designed directly.

SIMULATION MODEL AND ITS SUBSYSTEMS

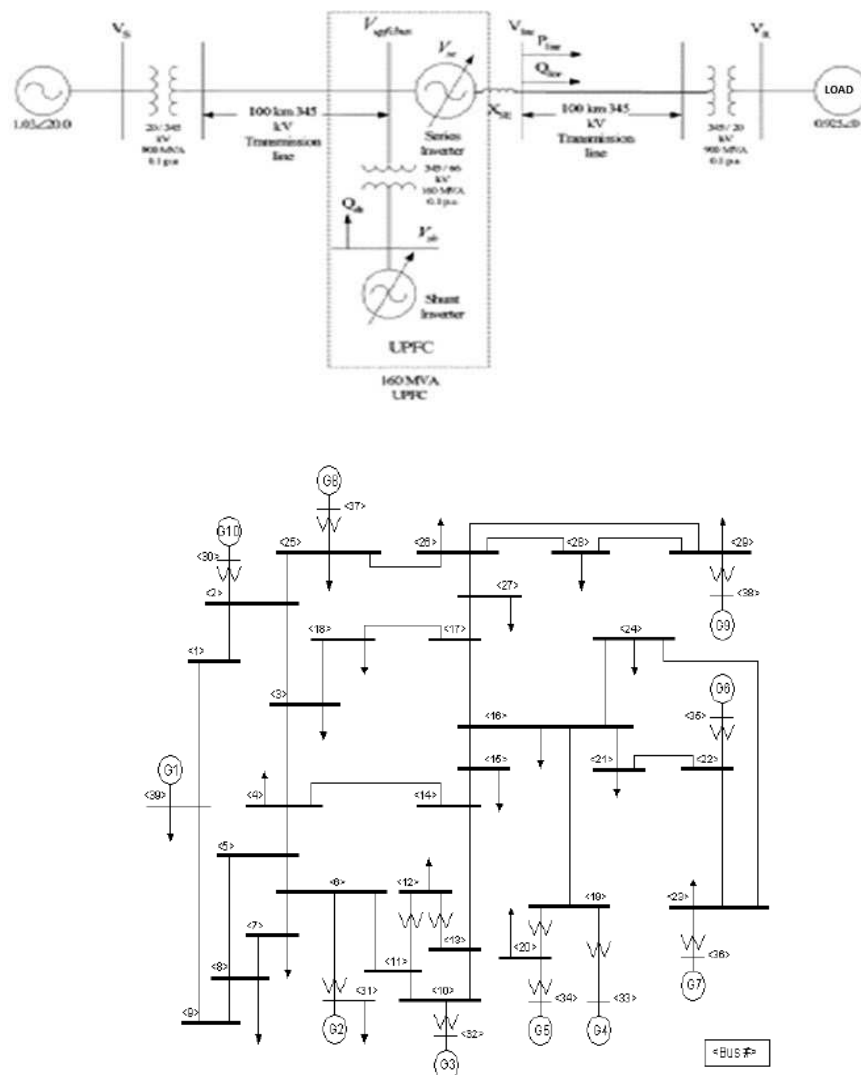


Figure 4: UPFC Connected in the IEEE 39 Bus System

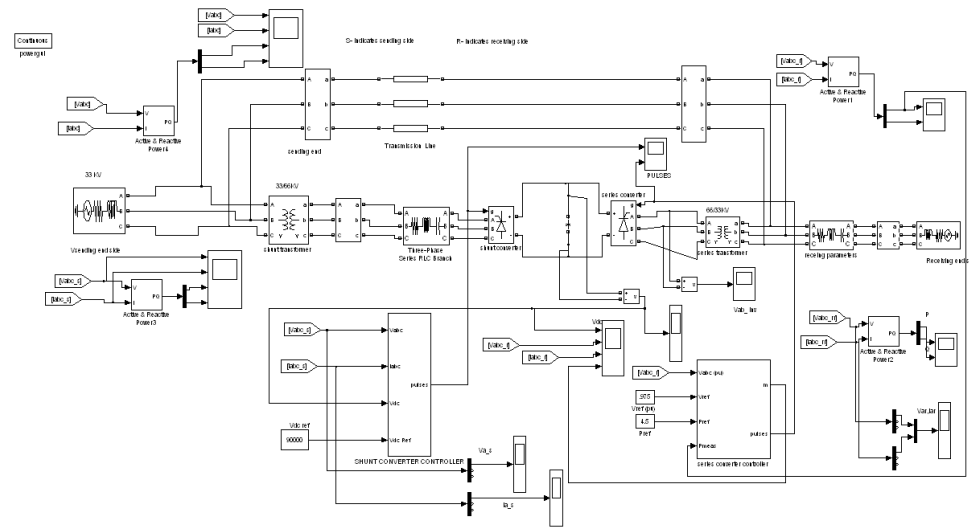


Figure 5: Simulation of PI Controller

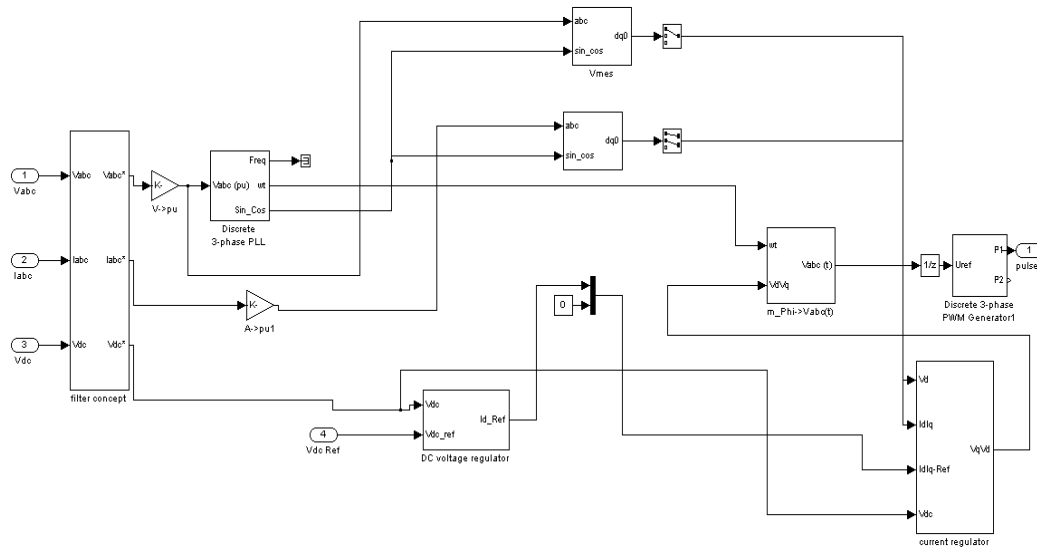


Figure 6: Shunt Converter Controller Using PI

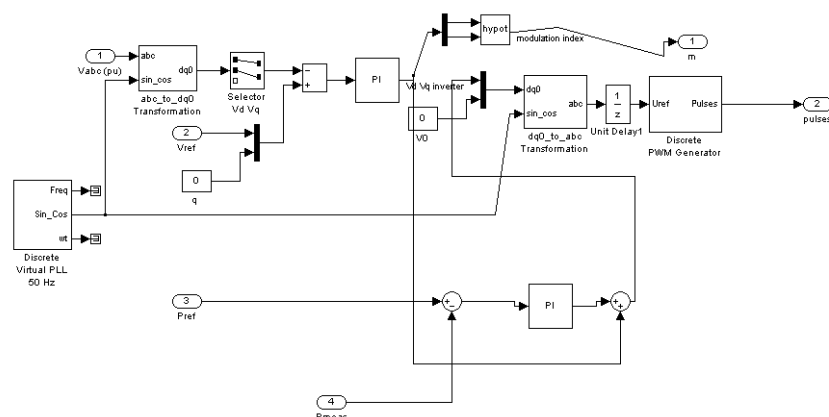


Figure 7: Series Converter Controller Using PI

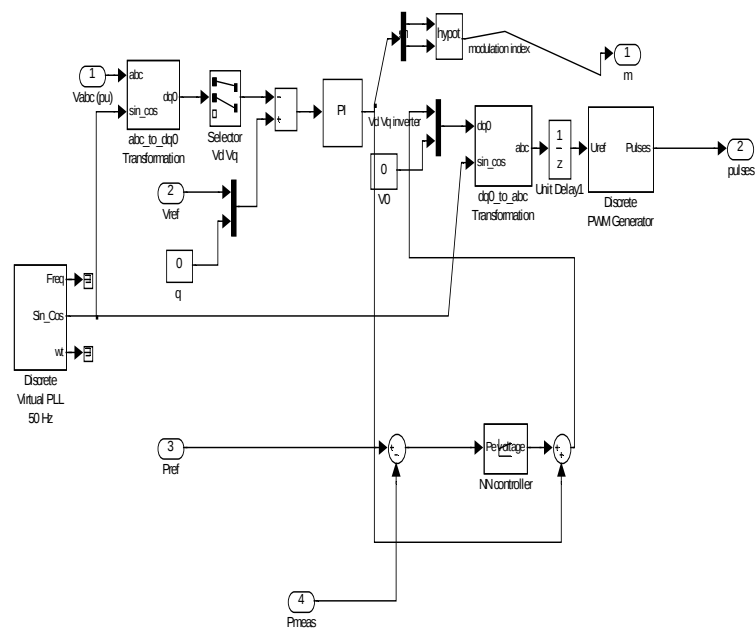


Figure 8: Series Converter Controller for NN Controller

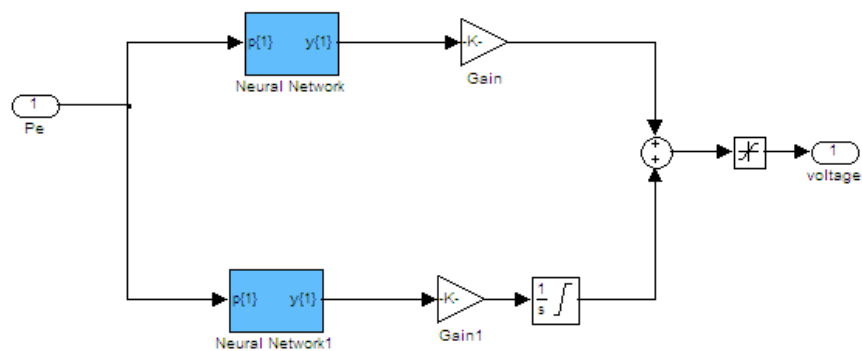


Figure 9: Subsystem for NN Controller Block

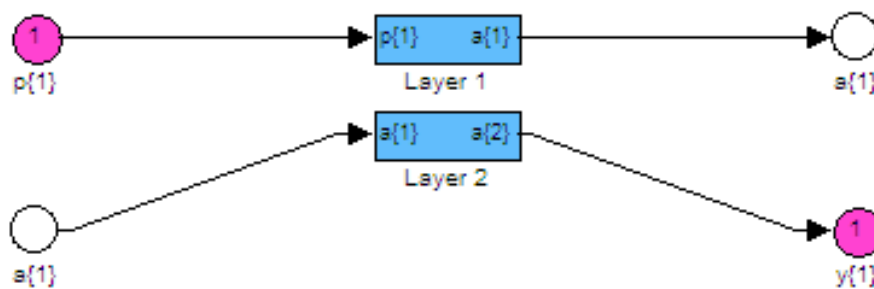


Figure 10: Subsystem for NN Controller Sub Block

SIMULATION RESULTS

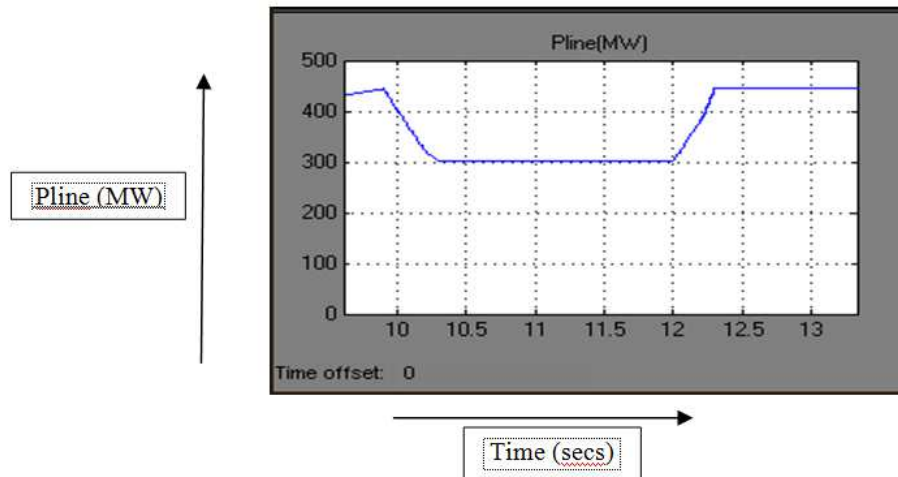


Figure 11: Response of Power System to Step Change in Transmission Line Real Power Reference

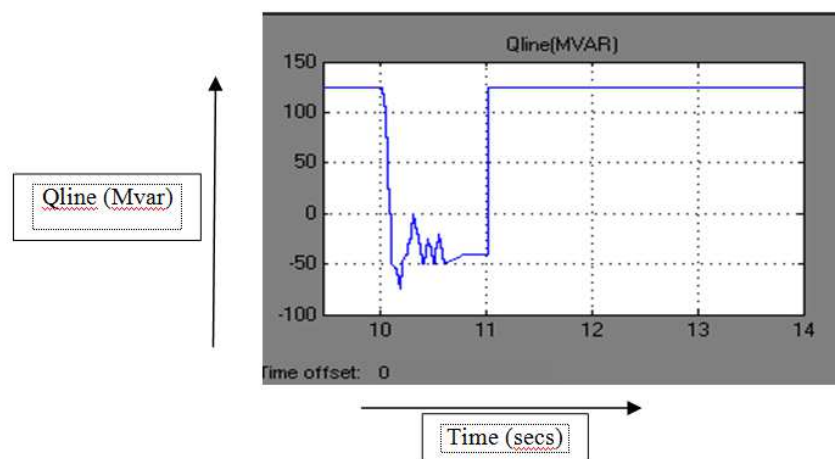


Figure 12: Response of Step Change in Reactive Power Reference

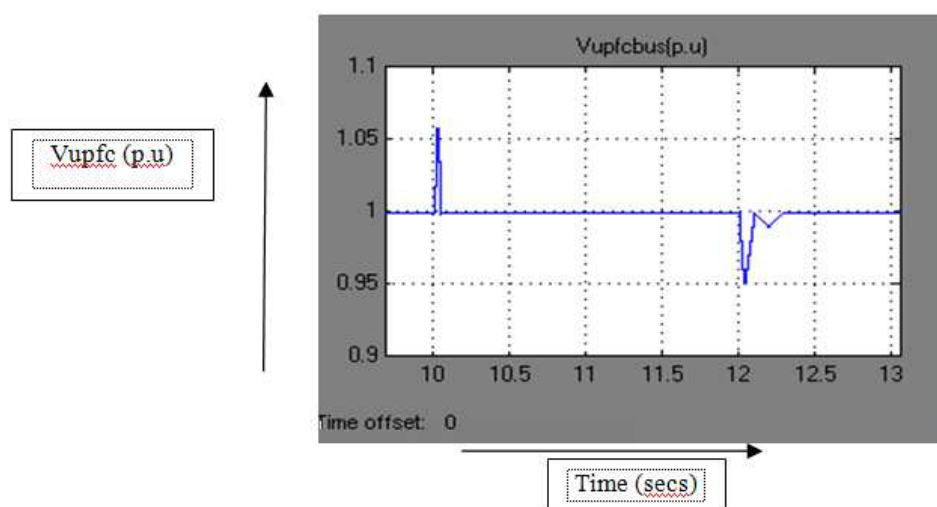


Figure 13: Response of UPFC Bus Voltage with Out Coordination

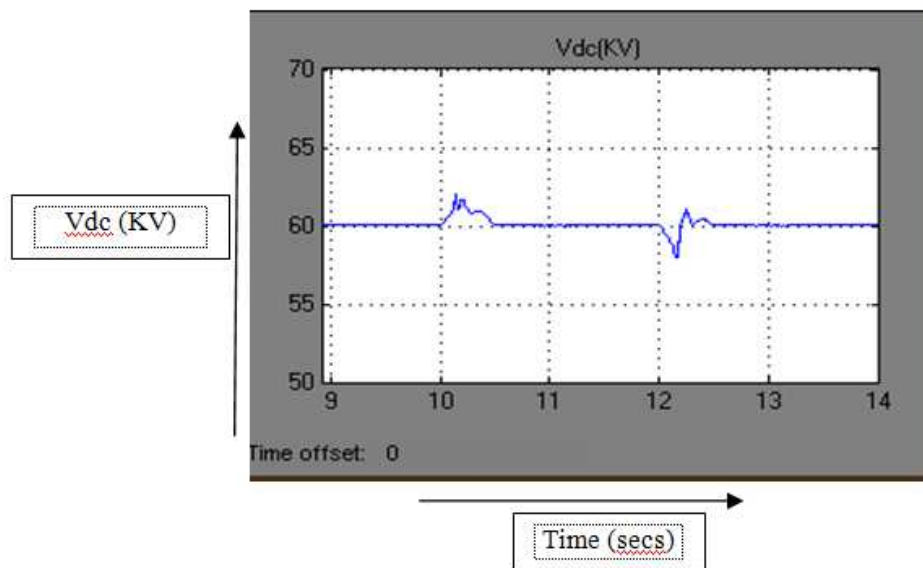


Figure 14: Response of DC link voltage with out coordination

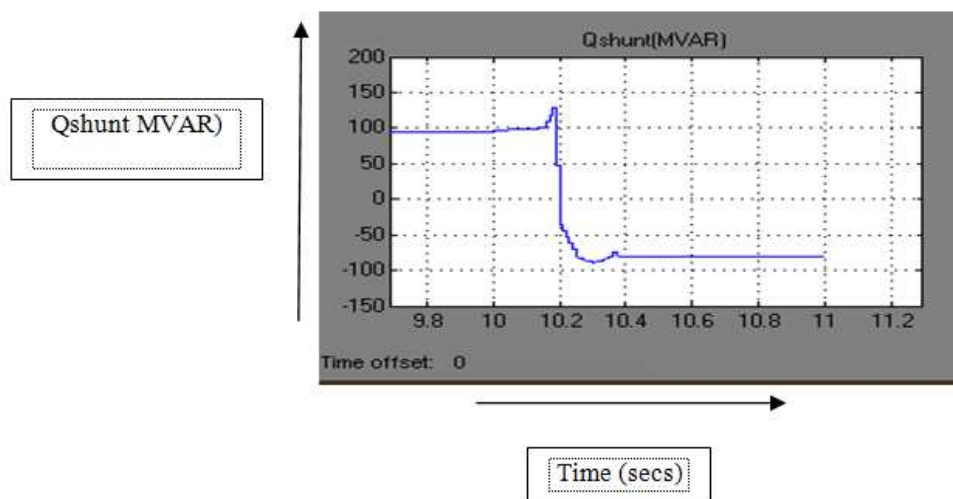


Figure 15: Response of Shunt Reactive Power Reference

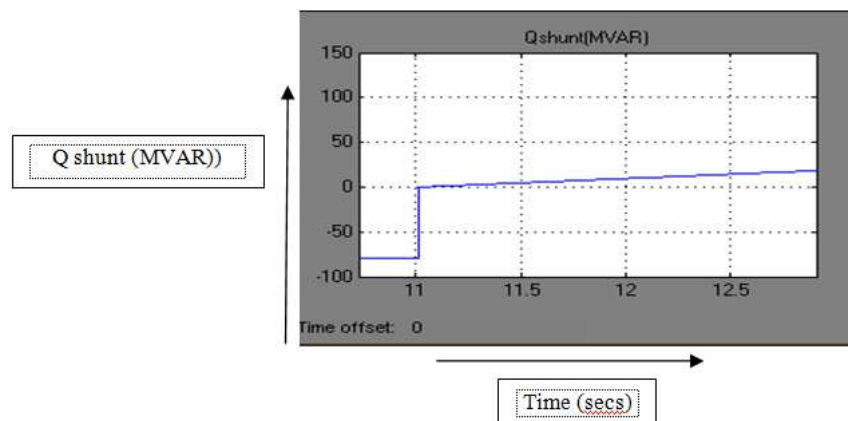


Figure 16: Response to Step Change in Reactive Power Reference

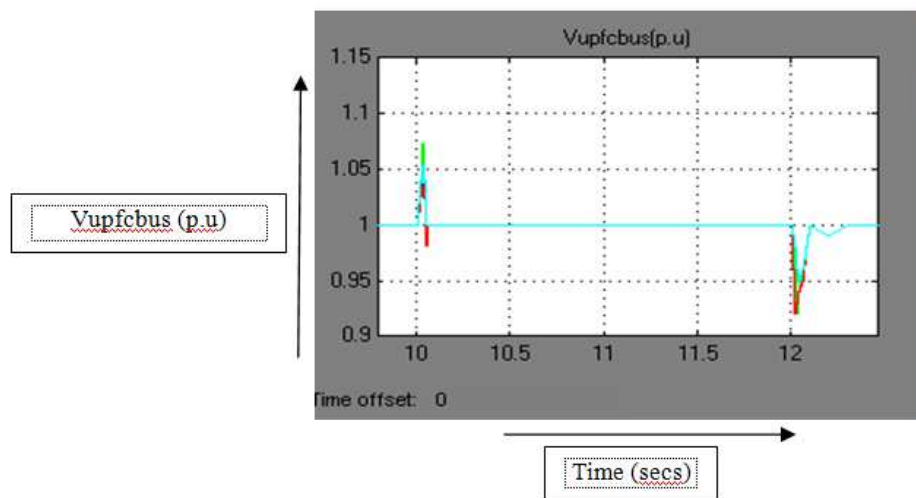


Figure 17: Response of UPFC bus voltage with ANN Controller (BLUE) & PI (RED)

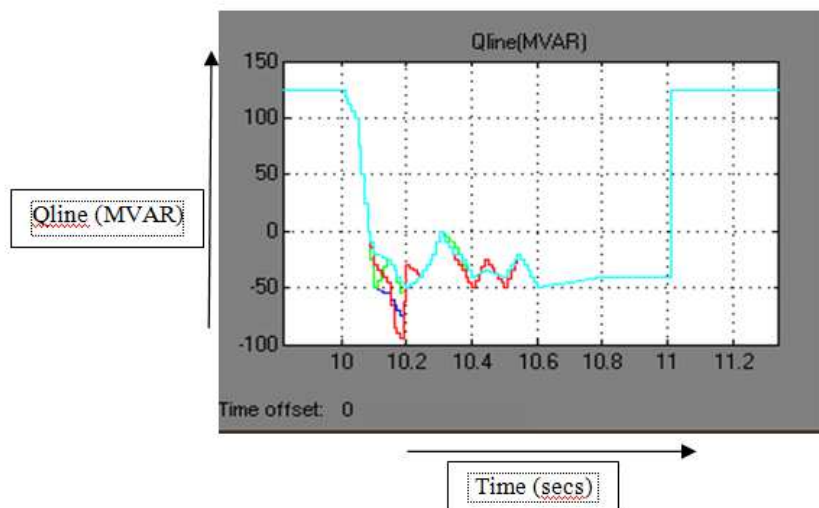


Figure 18: Impact of Reactive Power ANN (BLUE) Coordination Controller & PI (RED), without Coordination (GREEN)

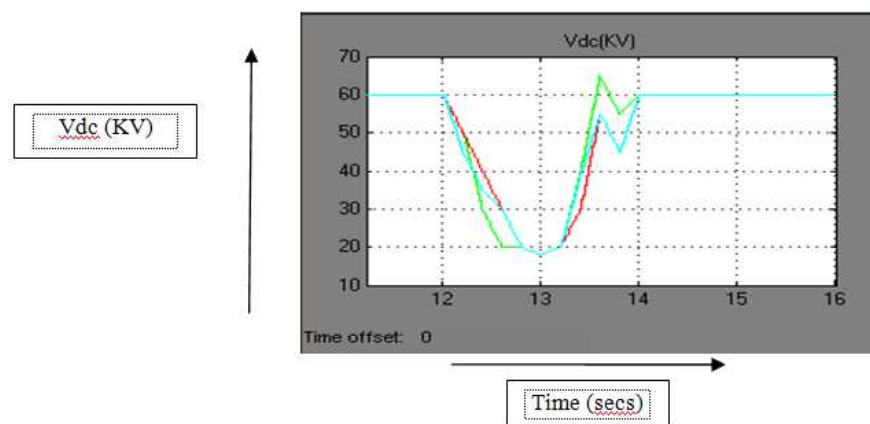


Figure 19: Response of DC Link Voltage with Real Power ANN Coordination Controller (BLUE) & PI (RED) without Coordination (GREEN)

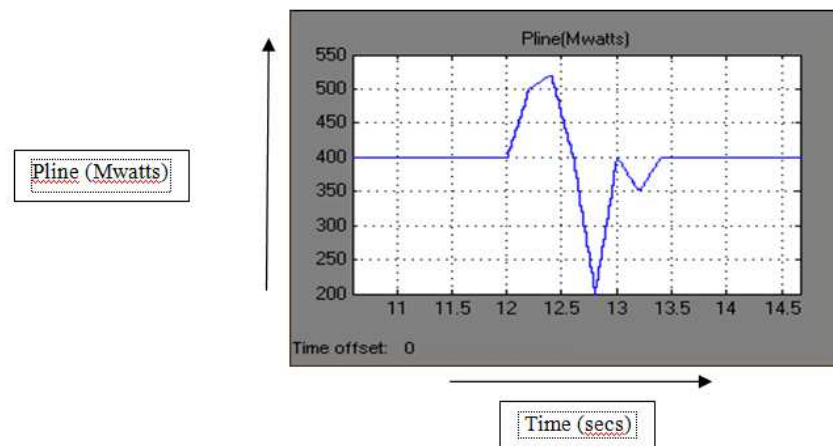


Figure 20: Response of Power System with Three Phase Fault

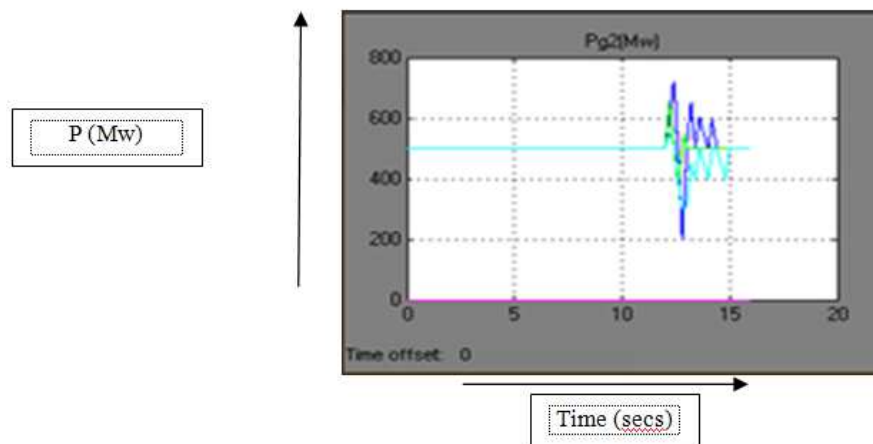


Figure 21: Electrical Power Without UPFC (DARK BLUE), with UPFC PI(GREEN),ANN Controller (LIGHT BLUE)

RESULTS AND DISCUSSIONS

Performance of Reactive Power Coordination ANN Controller

UPFC is connected between 26 & 39 bus in IEEE 39 bus system of 200km 345 transmission line and specification (Appendix A). Initial real power and reactive power (line) in the transmission line is 290MW & 125MVAR respectively & shunt reactive power is 80MVAR. When a step change in transmission line reactive power reference Decreases/Increases at 10sec there is a equal amount of Decreases/Increases of shunt reactive power is observed as shown in figure 12, 15, 16. with out reactive power coordination controller

With reactive power coordination ANN controller, the UPFC bus voltage Rise is reduced from 1.06 pu to 1.04pu as shown in Figure 17 and also the line reactive power settling time is reduced as shown in Figure 18.

Performance of Real Power Coordination ANN Controller

At 12 sec three phase fault is applied with real power fuzzy coordination controller the excessive dc link voltage is reduced from 2.5 kv to 1.8kv and recovery time is improved as shown in figure 19, and also the electrical power is very much stable as shown in Figure 21.

Table 1: Real and Reactive Power Coordination Controller

S. No		Without Coordination Controller	With Coordination Controller	
			PI	NN
1	UPFC bus voltage(pu)	1.075	1.06	1.04
2	DC Link Voltage Vdc KV	5	2.5	1.8

Controller	Voltage (pu)	Current (pu)	Pmw	Qmvar
	Sending Receiving	Sending Receiving	Sending Receiving	Sending Receiving
PI	0.975 0.96	0.9 0.8	290 290	125 125
ANN	0.975 0.97	0.8 0.77	290 290	125 125

CONCLUSIONS

In this paper a new real and reactive power flow control and coordination controller for a UPFC is presented. The basic control scheme is such that the shunt converter of the UPFC active and reactive controls the UPFC bus voltage/shunt reactive power and the dc linked capacitor voltage. The series converter controls of the power transmission line real and reactive power flow in the IEEE test bench. The contributions in this paper can be summarized as follows. Two important and main coordination conditions have been addressed in this paper related to UPFC control with different controllers (PI) and ANN controller. One of the problems of real power coordination is between the series control and the shunt converter control system. Second, the problem of more UPFC bus voltage variations during reactive power flow transfers requiring reactive power coordination. Including of the real power coordination ANN controller in the UPFC control system minimizes excessive DC linked capacitor voltage excursions and improves its recovery during transient conditions. MATLAB simulations have been conducted to verify the improvement in dc link voltage excursions in transient conditions.

Appendix 'A' [2]

A. Series Converter Control Parameters

- 1) Transmission line real power flow controller parameters

$$K_p = 0.1 \quad K_I = 4.0.$$

- 2) Transmission line reactive power flow controller parameters:

- a) Outer loop controller: $K_p = -0.1 \quad K_I = -1.0$.
- b) Inner loop controller: $K_p = 0.15 \quad K_I = 25.0$.

B. Power System Parameters

- 1) Generator parameters

$$\begin{aligned} L_{adu} &= 1.6 \quad L_{aql} = 1.5 \quad ll = 0.2 \quad L_{adl} = 0.835 L_{adu} \\ L_{aql} &= 0.835 L_{aql} \quad L_{fdl} = 0.10667 \quad r_{fdl} = 0.0005658 \\ L_{ld} &= 0.1 \quad r_{ld} = 0.01768 \quad L_{lq} = 0.45652 \\ r_{lq} &= 0.01297 \quad L_{2q} = 0.05833 \quad r_{2q} = 0.021662 \\ H(1) &= 3.15 \quad H(2) = 3.5. \end{aligned}$$

- 2) UPFC parameters

Dc link capacitor = 3000 μ F.
 Shunt converter transformer is rated at
 160 MVA, 345/66 kV, $X_{sh} = 0.2$ p.u.
 Series converter transformer is rated at 160 MVA.
 38.1/66 kV, $X_{SE} = 0.04$ p.u.

3) Exciter and power system stabilizer parameters

$$K_{stab} = 9.5 \quad T_W = 10.0 \quad T_1 = 0.05 \quad T_2 = 0.02 \\ T_3 = 3.0 \quad T_4 = 5.4 \quad T_R = 0.02 \\ K_A = 200.0 \quad T_A = 1.5 \quad T_B = 1.0 \quad T_E = 0.02.$$

4) Synchronous motor load parameters:

a) Rating: 900 MVA, 20 kV.

b) Parameters

$$X_{S1} = 0.14 \quad X_{MDO} = 1.445 \quad X_{23O} = 0.0 \\ X_{3D} = 0.0437 \quad X_{2D} = 0.2004 \quad X_{MQ} = 0.91 \\ X_{2Q} = 0.106 \quad R_{S1} = 0.0025 \quad R_{2D} = 0.00043 \\ R_{3D} = 0.0051 \quad R_{2Q} = 0.00842 \quad H = 1.0.$$

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